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STEREOSCOPIC FILMING OF RAPID PROCESSES BY TWO INDEPENDENTLY OPERATING MOVING PICTURE CAMERAS

by V. V. Garnov and A. S. Dubovik

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STEREOSCOPIC FILMING OF RAPID PROCESSES BY TWO INDEPENDENTLY OPERATING MOVING PICTURE CAMERAS

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STEREOSCOPIC FILMING OF RAPID PROCESSES BY TWO INDEPENDENTLY OPERATING MOVING PICTURE CAMERAS /116

A stereoscopic filming method is presented for producing stereoscopic pairs, within a certain allowable time period of desynchronization, by two cameras, each working independently. The size of the exposure base, therefore, is of no consequence as each camera has no direct connection with the other. Accuracy of frame synchronization depends on the parameters of filming. Due to the operation of two cameras with different frequencies of exposure there occurs a superpositioning of frame exposures -- "frequency pulsations." Soil dispersion caused by subterranean explosions is described as investigated by this method. Fulfillment of the conditions of this simultaneous exposure of frames depends on the stability of frequency exposure and for good results it is necessary to maintain exposure frequencies of an accuracy of ∿ 1%.

In the stereoscopic filming of various rapid processes by two motion picture cameras, particular importance must be attributed to operational synchronization of cameras necessary for simultaneous production of the exposed frames (stereopairs) (1, 2). With a disruption of operational synchronization dif- /117
ferent phases of progress of the process under investigation are registered on the photographs of a stereopair. This in turn prevents an exact reconstruction of the stereoscopic model. The exactness of synchronization depends on the methods of synchronization. In stereoscopic filming with an intermittent film drawing, the operational synchronization of motion picture cameras can be achieved by various methods which are selected in accordance with the parameters of the phenomenon under investigation and the filming scale as well as on the degree of desired accuracy of the stereomodel measurements. The latter is known to depend on the exposure base and on the distance of the object of filming (3).

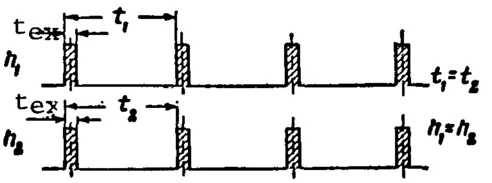

Fig. 1

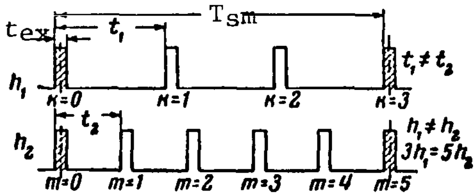

Fig. 2

When the filming is done from short distances and when the size of exposure bases is not large (up to ∿1m) it is convenient to use cameras supplied with specular stereoscopic attachments. With an increase of distance from the object there occurs a corresponding increase of the size of the base. If the base does not exceed 1.5-3m, it is possible to achieve a mechanical connection

/Numbers in the margin indicate pagination in the original foreign text.

between the two cameras. The cameras can then be connected kinematically and can be driven by a single motor. In that case the obtained synchronization is rigid and is within the limits of error of the kinematic pairs. A further increase of the exposure bases leads to constructional and operational difficulties, especially with the higher rate of filming (more than 50 frames/sec.).

For large bases (larger than 3m) and considerably high rate of filming, the synchronization of two cameras can be achieved by telemechanical connection. The main difficulty incurred with the use of this method is the necessity of construction of a complex and expensive electrical apparatus.

The enumerated methods of synchronization are based on direct interconnection of operating cameras. It is possible, however, to obtain stereoscopic pairs by the use of cameras, each working independently and having no direct connection with the other. In such a case, therefore, the size of the exposure base is of no consequence whatsoever. It will be shown that accuracy of frame synchronization depends on the parameters of filming. This method of obtaining the stereopairs, within a certain allowable time period of desynchronization, depends on the principle of "frequency pulsation." Under certain conditions during the operation of two cameras with different frequencies of exposure, there occurs a superposition (coincidence) of instances of frame exposure - "frequency pulsation." Then these points of "pulsation" correspond to simultaneous exposure of frames which in the case of stereofilming results in stereopairs.

Let us make a more detailed study of the nature of this process. With a synchronous operation of two cameras, their work may be presented graphically as shown in Fig. 1. Here the exposure frequencies h_1 and h_2 of the two cameras are equal and the exposure of each frame of one camera occurs simultaneously with that of the other. When two cameras operate at different frequencies of exposure ($h_1 \neq h_2$) it is easy to select their frequencies in such a manner as to have their ratio represented by whole numbers, prime with respect to each other. It is then possible to obtain simultaneously exposed frames as shown in Fig. 2.

For example, it is easy to represent various ratios of exposure frequencies thus: /118

$$\frac{h_1}{h_2} = \frac{k}{m} = \frac{2}{3}; \frac{3}{4}; \frac{4}{5} \cdots \text{ or } \frac{h_1}{h_2} = \frac{3}{5}; \frac{5}{7}; \text{ etc.} \quad (1)$$

In this case numerator k and denominator m indicate the number of coincident frames of each camera.

Then the following relationships are true:

$$T_{st} = kt_1 = mt_2$$

where t_1 and t_2 are time periods between two consecutive frame exposures.

Frequency of stereoscopic exposure is determined from the expression

$$h_{st} = \frac{1}{T_{st}} = \frac{1}{kt} = \frac{1}{mt_2} = \frac{h_1}{k} = \frac{h_2}{m} \tag{2}$$

From expression (2) it follows that:

$$h_1 = kn_{st}$$

and

$$h_2 = mn_{st}$$

The difference of these expressions gives:

$$h_1 - h_2 = h_{st}\ (k - m),\ \text{whereby}$$

$$h_{st} = \frac{h_1 - h_2}{(k - \bar{m})}; \tag{3}$$

$$h_{st} = h_1 - h_2 \tag{4}$$

if $k - m = 1$.

For independent operation of cameras, the pulsation law holds for all /118
cases of frequency superpositions (for $k/\bar{m}$ as in (1)), but the character of pulsation is not always the same because then there is a possibility of a near, but not exact, coincidence of frames.

$$\frac{h_1}{h_2} = \frac{t_2}{t_1} = \frac{2}{3}$$

This is illustrated in Fig. 3, where the two top lines show operational time characteristics of two cameras with the ratio $k/m = 2/3$, where there exists a strict coincidence of exposure instants at the "pulsation" points. Lower lines represent operational time characteristics of cameras with somewhat shifted phases which results in the non-exact coincidence of exposure instants at "pulsation" points.

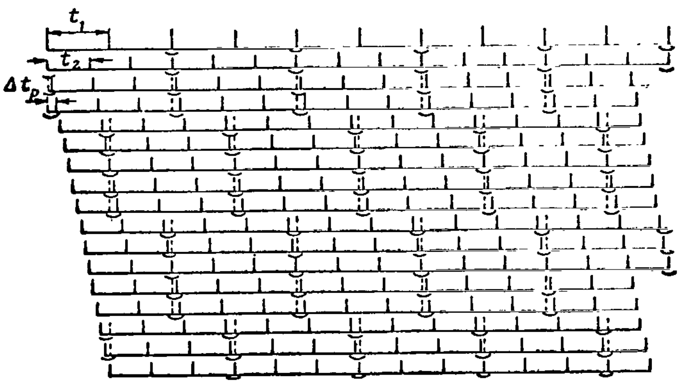

Fig. 3

The maximum non-coincidence of frames at "pulsation" points determines the possible desynchronization time Δt_r of this method. From the analysis of graphics for various shift-values, with variable values of k/m and constant value of (k - m) = 1, it is not difficult to obtain the following relationships:

$$\Delta t_r = \frac{t_1 - t_2}{2}, \text{ or for a general case with } (m - k) \neq 1:$$ /119

$$\Delta t_r = \frac{t_1 - t_2}{2(m - k)} = \frac{T_{st}}{2mk} = \frac{t_1}{2m} = \frac{t_2}{2k} = \frac{1}{2mn_1} = \frac{1}{2kn_2} \tag{5}$$

These relationships can also be proved using the theory of numbers methods. If the possible time Δt_r of desynchronization is assumed to be equal to the allowable time $\Delta t_{r.al.}$ of desynchronization or less than it, time Δt_r can be neglected because then it does not affect the accuracy of the stereoscopic determinations. The allowable time of desynchronization (the allowable error in synchronization) is determined on the basis of theorems of stereophotogrammetry. It is known (2, 4) that the parameters of ground stereoscopic exposure are bound by the expression:

$$y = Bf/p, \tag{6}$$

where y is the distance of cameras from the object under investigation (the remoteness); B - the exposure bases; f - the focal distance of cameras; and p - the measured parallax.

Differentiating this expression with respect to p and replacing the value of p as given in (6) we obtain:

$$dy = \frac{Y}{BM} dp \qquad (7)$$

where dy is the error in determination of remoteness caused by error in measurement of parallax - dp.

Since desynchronization time t_r should not result in errors in determination of y by amounts greater than the allowable errors dy,

$$\Delta t_{r.al.} \; V \leq dy, \qquad (8)$$

where V is the velocity of the process under investigation.

From expressions (7) and (8) it follows that:

$$\Delta t_{r.al.} \leq \frac{y}{BMV} dp \qquad (9)$$

If the error in measurement of horizontal parallaxes dp is expressed in terms of allowable tolerance in the photographic image, then:

$$dp \approx \frac{1}{N_{st}} \approx \frac{1}{2N} \qquad (10)$$

where N_{st} is the allowable stereoscopic print tolerance and N is the allowable photographic tolerance.

$$\Delta t_{r.al.} \leq \frac{Y}{2BMVN} \qquad (11)$$

This expression permits determination of the allowable time of desynchronization on the basis of the principal parameters of exposure and the process under investigation. Substituting the value of t_r for (5) in expression (11) it is possible to find all parameters of exposure for which the possible time period of desynchronization is equal to or less than its allowable value: /120

$$V \leq \frac{4mn_1y}{BMN} = \frac{4kn_2y}{BMN} \qquad (12)$$

This formula permits the evaluation of the principal parameters of exposure. Knowing the frequency of stereoscopic exposure h_{st} (2), (3), (4) and the duration T of exposure registration it is possible to determine the total number of stereopairs obtained:

$$\sum = h_{st}T = \frac{h_1 T}{k} = \frac{h_2 T}{m}$$

Motion picture camera I   Motion picture camera II

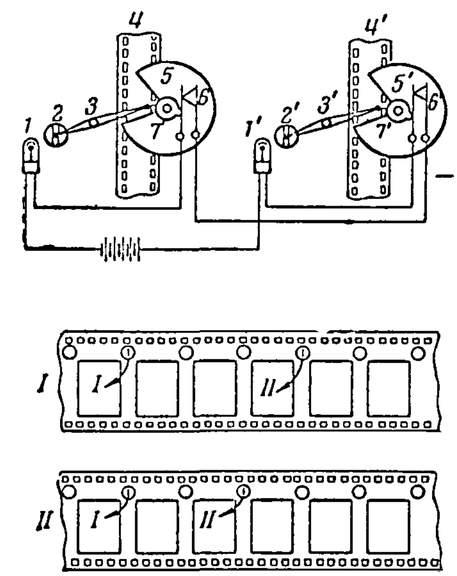

Fig. 4

This expression is true for the processes of constant speed value (V_{max} = const.). In investigation of processes whose velocities vary (for example from V = 0 to $V = V_{max}$) the number of stereoscopic pairs is considerably larger, because, with velocities $V = V_{max}$, the number of stereoscopic pairs consists not only of frames which correspond to "pulsation" points but also of other intermediate frames.

In practice, the method of stereopairs based on the principle of "frequency pulsation" was used in investigation of soil dispersion caused by subterranean explosions. Two moving picture cameras were used for stereoscopic filming. The cameras were partially modernized (frames were marked, levels were installed, replaceable obturators and time meters were used). The frequencies of exposure varied from 20 to 30 frames/sec. The process velocity was that of 50 to 150 meters/sec. The exposure base varied within the range of 10 to 30 meters.

The processing of the enlarged prints was made on the stereometer SM-4

(Russian: CM-4). The results of measurements were used for reconstruction of trajectories of soil dispersion. In spite of the imperfection of motion picture cameras with regard to requirements of photogrammetry, the accuracy of coordinate system determination was that of 1/600 - 1/800 of the y-value.

For rapid recognition of stereopairs on the films, the apparatus was provided with special markers for imprinting the light signs on the frames which corresponded to simultaneously open obturators. In Fig. 4, 1-1' indicate neon lights connected in series and burning at the simultaneous closing of contacts 6-6'; 2-2' are slotted diaphragms; 3-3' are lenses for formation of images of slotted diaphragms on the moving films 4-4'; 5-5' are camera obdurators; 6-6' indicate contacts closing by cams 7-7' which are rigidly connected with the obturate axis; I, II are light images indicating stereopair frames.

With a small number of frames, the stereopairs are easily located on the enlarged prints. A 3 to 5 times enlargement of the frame (for equal scale of exposure) causes the corresponding enlargement of the dimensional error of image, when this error lies within the limits of photographic tolerance. Therefore, the stereopairs are easily located by simple measurement of image dimensions. With a large number of frames, first stereopairs are located by measurement and the subsequent ones with the use of ratio $k/\bar{m}$. With such methods of filming not all frames are stereopairs. It must be observed, however, that usually the film bearing stereopairs is used not only for stereoscopic measurements, but is in itself a document, a pattern for making a motion picture film and for making measurements of the phenomenon under investigation.

With the usual motion picture filming used for the study of the phenom- /121
ena of explosions, the motion picture is duplicated and the filming is done by the use of two or three cameras. In such cases the use of "frequency pulsation" methods provides additional information. It must be noted also that the fulfillment of conditions of "pulsation" depends on the stability of frequency exposure. Therefore, an analysis was made of the effect produced by instability errors on synchronization. In the established work regimen the sign of exposure frequency error is subject to constant changes. As was found by a series of experiments, for sufficiently good results (at $h \leqslant 100$ frames/sec.) it is necessary to maintain exposure frequencies of an accuracy of $\sim 1\%$.

Conclusions.

The analyzed method of obtaining stereopairs by the use of two motion picture cameras permits stereoscopic filming (for measurement purposes) with any bases of exposure without the necessity of especially constructed complex apparatus for synchronization.

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REFERENCES

1. Orlov, P. M. Ground photogrammetry (Nazemnaya fotogrammetriya). Publication of M.G.M.I., Moscow, 1938.

2. Lobanov, A. N. Phototopography (Fototopografiya). Geodes. Publication, 1960.

3. Skiridov, A. S. Stereophotogrammetry (Stereofotogrammetriya). Geodes. Publication, Moscow, 1959.

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